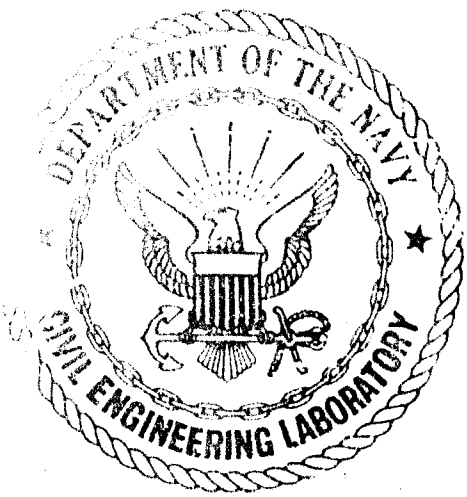

CR 78.010

CIVIL ENGINEERING LABORATORY
Naval Construction Battalion Center
Port Hueneme, California

Sponsored by
NAVAL FACILITIES ENGINEERING COMMAND

TEST PROGRAM FOR PHYSICAL CLEANING AND FOULING PREVENTION IN REVERSE OSMOSIS SYSTEMS

February 1978

An Investigation Conducted by
MEMBRANE SYSTEMS
WET Incorporated
Westlake Village, California

N68305-77-C-0014

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20 ABSTRACT (Continue on reverse side if necessary and identify by block number)

A number of in-situ physical cleaning methods were tested as alternatives to using chemicals to clean reverse osmosis and ultrafiltration membranes. Flow surging, air surging, continuous air addition and ultrasonic cavitation were used alone and in combination with each other as cleaning methods. Ultrasonic cavitation alone and in conjunction with flow surging

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were the most effective of the methods tested.

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INTRODUCTION

This report covers work accomplished under Contract N68305-77-C-0014, "Test Program for Physical Cleaning in Reverse Osmosis Systems".

The tests consisted of operating three membrane systems:

1. A Single Tube Reverse Osmosis module with six square feet of membrane for 600 psi service (cellulose acetate membrane).

2. A Seven Tube Reverse Osmosis module with seven square feet of membrane for 600 psi service.(cellulose acetate membrane).

3. A Seven Tube Ultrafiltration module with seven square feet of membrane for 125 psi service (polysulfone membrane).

The tests included establishment of baseline data on each of three Grey Water wastes-laundry, shower and galley, and a composite of the three waste waters. Tests covered operation, fouling characteristics and general performance of a number of different modes of cleaning.

The objective of these tests was to establish physical means of maintaining a high performance membrane system instead of the more common chemical cleaning currently in use. The elimination or reduction in chemicals will reduce logistics support as well as simplify operator requirements. Current technology requires extensive chemical cleaning on grey water feeds. An in-situ physical cleaning process will enable a more compact system for comparable cleaning action, when compared to chemical processes now available.

This program was conducted over a ten month period, seven months of which were actual tests. First tests were in July 1977, final tests were in February of 1978.

SUMMARY

Design Concept

This program was conducted utilizing externally pressurized membrane tubes in three different configurations:

1. A "single tube" Reverse Osmosis module, consisting of the matrix of three 1" OD stainless "U" tubes. The open ends of the tubes enable installation of the six foot long membrane tube assemblies, six assemblies total being used. In the externally pressurized tubular configuration, permeate travels inward towards a tube located centrally within the membrane tube assembly and finally out of the assembly via polypropylene tubes to a collection tank. Ultrasonic transducers were secured in various patterns to the sides of the "U" tubes.

2. A "seven tube" Reverse Osmosis module comparable to those used in production systems where seven six foot long membrane tube assemblies are installed in a 2½" pipe size pressure vessel. One ultrasonic transducer was mounted on the end of the vessel.

3. A "seven tube" Ultrafiltration (UF) module similar to 2. above but enclosed in a plexiglass pressure vessel. NOTE: Since the UF module exhibited exorbitant flux declines, its graphs have been omitted from this report. Also, since the quantity of data produced during the test program was voluminous indeed, only a few of the graphs have been selected for this report.

These test units were installed with sufficient pumping and control valve units to facilitate flow and pressure control during the test program. The following modes of operation and cleaning were conducted with this system:

1. Normal operation, with intermittent or post operation chemical cleaning.

2. Normal operation with intermittent or post operation ultrasonic cleaning. Ultrasonics were operated at 0 psi, 50 psi and 100 psi for the UF, 0 psi, 300 psi and 550 psi for the two RO units.

3. Flow surging, increasing flow rates at low and high pressures.

4. Air feed, continuous air addition or surging the system with intermittent air pulses.

Modes 2, 3 and 4 were conducted with and without chemical cleaning solutions.

Evaluation (Ref. Table 1 & 2)

Task I - Base line, No Cleaning

a. Laundry feed was run with moderate decline in permeate flux (19 to 26%) on all membrane units. There would appear to be no problem in operation with this feed alone.

b. Galley waste only, also operated well with 8 to 27% decline in flux. There should be no problem with this feed alone.

c. Shower waste was no problem to handle. A 1 to 10% decline in flux was demonstrated in six hours.

d. Composite feed had from 15 to 34% drop in flux in the six hour run. Specific cleaning procedures would be required at less than six hour intervals to insure good average overall permeate production. (See Table 3)

Task III - Circulation Rates.

This task was accomplished in two runs of sixty-two hours of continuous operation. The first run was at pH 8.4 and the second run was at pH 6.7 to 6.8. Each run consisted of twenty hours continuous running at low flow, twenty hours at medium flow and twenty hours at high flow

rates. Velocities varied from 3 ft/sec to 9 ft/sec during these runs. RO-1 could only operate with one pump since the flow meter continued to blow apart over 4 GPM. (It finally burned out the motor). Membranes were cleaned after each twenty hour section.

a. Low flow rates gave generally high flux declines. As much as 86% decline in the twenty hour period. The RO was superior in the low pH ranges and the UF was much better in the high pH ranges.

b. Medium flow rates showed better stability in the low pH range. RO flux declines ranged from 19 to 52%. The UF showed moderate stability at medium flows in all cases; in fact at the end of the twenty hour runs the UF had the same or greater flux. This is apparently the optimum velocity for the membrane turbulators.

c. High flow rates showed good stability in both runs for the RO modules, with overall better performance in the lower pH range. RO flux declines varied from 15 to 34%. The high pH UF run was fairly stable, a 28% flux decline; at the low pH the UF run lost 80% of the initial flux. See graphs 1A, 1B.

Task IV - Ultrasonic Baseline.

Ultrasonics baseline was run using ultrasonics at high pressures, medium pressures, low pressures and no pressure to evaluate comparative cleaning action. 0 psi cleaning showed a loss of 9 to 19% in the three systems, the UF being the poorest. Medium and high pressure ultrasonics were not nearly as effective. The chemical cleaning baseline was approximately the same performance as ultrasonics at 50 psi. See Graph 2.

Task VII - Air Surging.

Air surging and air surging with ultrasonics were conducted at minimum pressure, medium pressure (50 psi for UF, 300 psi for RO) and normal operating pressure. Fouling rates were very high, so a ninety hour portion of this test time was transferred to subsequent testing of flow surging and low pressure ultrasonics. At the conclusion of this the UF was so fouled that it could not be cleaned, so it was not used in the final test segment.

Task VIII - Continuous Air.

Continuous air at full and at medium (50 psi for UF, 300 psi for RO) pressures, with and without ultrasonics was run, a four segment test.

a. Continuous air at full pressure, periodic chemical cleaning, maintained uniform output from beginning to end for the RO, the UF dropped 49% in flux.

b. Continuous air feed with ultrasonics at 0 psi had a significant flux decline, 32 to 38% more than the constant run plus chemicals.

c. Continuous air at 300 psi (50 psi for UF) had good stable performance for the RO, 16 to 26% flux decline. The UF declined in flux 55%. See Graph 3A.

d. Continuous air at 300 psi plus ultrasonics at 0 psi was quite comparable to air at 600 psi, with slightly greater flux declines. The continuous air runs required hand cleaning after the sequences were completed to raise the flux back to acceptable levels. The UF flux did not recover at all. See Graph 3B.

Task IX - Flow Surging.

Flow surging was conducted at various pressures (50 psi, 300 psi and 550 psi for the RO) with and without ultrasonics, except at the maximum pressure when no ultrasonics were used, a total of five sequences of tests. The UF was not operated.

a. Flow surging at 50 psi showed moderate loss in flux (30 to 34%) during the tests. Hand cleaning was required after this test. See Graph 4A.

b. Flow surging plus ultrasonics showed excellent results, 2 to 3% flux loss at the end of thirty hours, and no special cleaning after the run. See Graphs 4A and 4B.

c. Flow surging at 300 psi also showed 2 to 11% decline in flux. The post run chemical clean was acceptable.

d. Flow surging at 300 psi plus ultrasonics was quite stable but not as good as at 50 psi. See Graphs 4A and 4B.

Flow surges at 600 psi were stable, but due to some initial fouling the flux was generally lower. Negligable flux loss occurred in both RO-1 and RO-2. Hand cleaning was required after this run.

Task VII (Revised) - Flow Surging, Ultrasonics.

The deleted portion of air surging, Task VII was replaced with Task VII (Revised), forty hours of flow surging at 50 psi with ultrasonics and forty hours of ultrasonics only at 0 psi. This was the last sequence of testing. See Graphs 5A and 5B.

a. Flow surging at 50 psi with ultrasonics gave very stable results for about thirty-seven running hours (18% flux drop). See Graph 5B.

b. Ultrasonics at 0 psi maintained a very stable run performance for the first thirty hours, then dropped about 30% over the remaining test. Both runs showed good stability if tied into a slightly different cleaning cycle.

Total running time for all tests and cleaning was approximately 900 hours.

Conclusions

a. The following cleaning methods proved most successful in producing a shallow permeate flux decline throughout the testing period:

1. High Flow Velocity (7-9 ft/sec)

2. Flow Surging (50 psi - 300 psi)

3. Flow Surging With Ultrasonics (50 psi)

4. Ultrasonics (0 psi)

5. Continuous Air (300 psi) + Ultrasonics (0 psi)

6. Continuous Air (300 psi)

b. The following cleaning methods proved most successful in producing a cleaning effect comparable to chemical cleaning procedures throughout the testing period:

1. Continuous Air (600 psi) + Ultrasonics (0 psi)

2. Ultrasonics (0 psi - 50 psi)

There are several non-chemical means of maintaining consistent membrane performance in grey water (galley, laundry and shower composite feed) processing.

c. The specific means of processing seem to be somewhat pH sensitive. Three ranges of pH (4-5, 6-7 and 8.4) were used and general RO performance seemed better in the pH 6-7 range, but no effort was made to optimize pH in these tests. The UF performed best in the pH 8.4 range.

d. High velocities, in the range of seven to nine feet per second, gave superior performance compared to lower velocities in nearly all respects. Some improvements could be made in the module design to minimize dead flow space and center the tubes uniformly in the flow path. The single tube unit has slightly better flow distribution, and thus is more effective in lower velocity ranges. The turbulators used in the early series of tests lost their efficiency when velocities were over seven feet per second. Build-up of eddy currents behind the wire caused noticeable fouling at 8-9 feet per second.

e. Ultrasonics, either alone or with other cleaning means, showed generally good cleaning characteristics. There was no effort to optimize the ultrasonics design in this project. The side mounted transducers and the end mounted units both seemed to clean comparably over the whole test series, one slightly better under one set of operating conditions than the other. Following are the superior ultrasonics modes:

1. Ultrasonics at 0 psi, no flow, plus periodic chemical (every 6-8 hours) clean.

2. Ultrasonics plus flow surge at 50 psi and high flow.

The other modes of cleaning which appeared to be very good were continuous air feed at 300 and 600 psi with and without ultrasonics for the RO units, plus chemical cleaning every 6 to 8 hours. Continuous air feed without ultrasonics seems to require significant hand cleaning when fouling occurs which makes it less desirable than the ultrasonics modes above.

It is possible that at optimum pH and flow, the system would operate consistently with only one chemical cleaning per day, using either the 50 psi flow surge plus ultrasonics or the 0 psi ultrasonics. The curves on 50 psi flow surge are all more stable than the 0 psi tests, and would be the first system to recommend. Any future system should be designed for accomodation of air, flow surge plus ultrasonics, thus enabling proof testing over a longer time run than this test series could cover.

Recommendations

The following are recommendations for future development:

1. An optimization study of the membrane module should be conducted. Because of the severe fouling characteristics of grey water such a system must be a tubular design, in order to permit effective cleaning throughout the membrane life cycle. This test program evaluated externally pressurized tube but internally pressurized tubes as well as inside-outside pressurized (pat. pending, W.E.T., Inc.) tubes could also be tested. The primary advantages of the inside/outside tubular configuration is that pressures higher than other configurations (e.g., internally pressurized tubes, spiral wound and hollow fiber) can be used while increasing packing density by 50% to 70% over the externally pressurized tubes and as much as 115% over the internally pressurized tubes.

2. The ultrasonic cleaning conducted during this test program indicated a great potential for physical cleaning of membranes in-situ. Optimization of this system would be necessary to realize this potential.

3. The iron materials, however few, caused cleaning difficulties above and beyond what was anticipated from the grey wastewater feed source. No iron should be allowed in future system materials. Bronze, stainless steel and fiberglass reinforced materials would be suitable for high pressure elements, plus PVC for low pressure pipe and fittings.

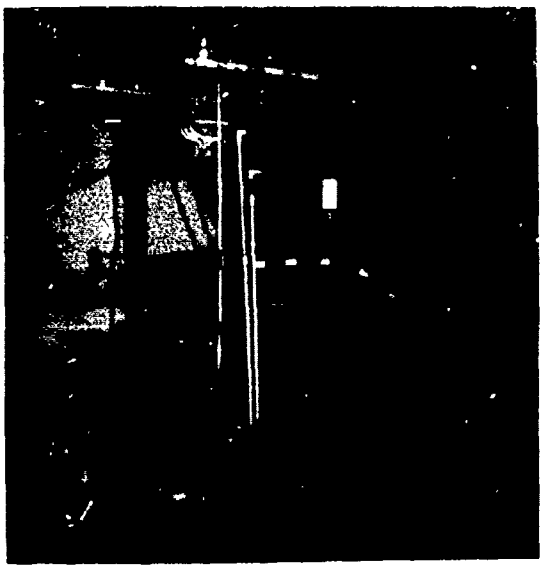
4. As a result of the membrane cleaning test program the best results were received using a cleaning procedure as follows:

a. Flow surging with ultrasonic cavitation occurring at 30-60 psi or Ultrasonic cavitation alone at 0 psi or 30-60 psi.

b. At the end of the daily water production quantity (e.g. 20-22 hours), a chemical cleaning solution is used consisting of Type 1 military detergent (500 mg/l), EDTA (500 mg/l), commercial enzyme (100 mg/l), sodium hypochlorite (100 mg/l), adjusted to pH 6-7. This cleaning solution will be recirculated for 1-2 hours and allowed to sit in the modules until the next day's start up.

TEST PROGRAM

Test Configuration



The test system for this program consisted of both contractor furnished equipment and Government furnished equipment, arranged into two primary subsystems; the Membrane Processing Systems and the Ultrasonic Systems.

1. The Membrane System consisted of a common feed and flush section and three separate membrane loops as follows:

a. RO-1 was a single tube reverse osmosis loop, suitable for pressures to 1000 psi. This loop had both a 4 gpm and a 4.5 gpm pumping unit with suitable control. Both pumps were supplied from a common header and pump discharge went into a common discharge header connected to the module. Flow rate was regulated by using one or both pumps (P-2 and P-3 or both in parallel). Pressure control was via a ball by-pass valve and in parallel a spring balanced pressure control valve. Pressure drop was measured across the R. O. module. Flow rate (concentrate, was measured by use of the sample valve which was used when the concentrate return valve was closed. The membrane module consisted of three 1" OD stainless steel "U" shaped tubes, each containing two 5/8" OD by 36" long externally pressurized membrane and core assemblies in each leg of the "U" tube. Therefore, six square feet of membrane surface area (1 ft^2 per leg of the "U" tubes) was enclosed in this configuration. Permeate was collected by polypropylene tubes connected to headers at the open end of the "U" tubes which drained into a common permeate tank. Samples and flow rates were taken from each of the six permeate tubes. Ultrasonic transducers were mounted along the sides of the legs of the membrane module "U" tube legs. (See Figures 1 and 2)

b. RO-2 contained seven tubes within a single pressure vessel unit which is a production size module. This unit was also supplied from the common header. The main pressurization pump, P-4, provided approximately 20 gpm feed to the circulation pump P-5. The circulation pump was a "canned" submersible pump suitable for continuous operation at 660 psi @ 200°F. Circulation flow rate was regulated by a ball valve on the discharge side of this pump, and the flow rate was determined by measuring the differential pressure across the pumps in conjunction with the pump performance curve.
The membrane module was a 2½" OD schedule 40 stainless steel pipe with seven sets of two 36" long membrane tubes, totaling seven square feet of membrane surface area. Permeate from each tube set (2 tube) was collected through a polypropylene tube which discharged into the common permeate tank. Samples and flow rates were determined from these permeate tubes. System pressure was maintained by a high pressure ball valve. Concentrate discharge rates and samples were obtained by opening the sample valve and shutting the concentrate return valve. The ultrasonic transducer was secured to the end of the module as shown in Figure 1.

c. The ultrafiltration module was a seven tube module unit similarly configured to RO-2 except that the pressure vessel was plexiglass and the permeate was collected from a single tube outlet. From the common feed header the feed was supplied into a multistage boost pump, P-6, capable of 5 gpm @ 100 psi. A by-pass valve around P-6 was used to regulate feed rate and pressure. The feed then went through a circulation rate control valve and finally to a circulation pump. P-7 (identical to P-5). Circulation rate was controlled by an inlet valve on P-7 and was determined by measuring the differential pressure across pump P-7 in conjunction with the pump performance curve. Concentrate flow rate and system pressure were regulated by a back pressure ball valve and the by-pass valve around P-6, operated simultaneously. Maximum system pressure, due to temperature and stress considerations, was 125 psi. Samples and concentrate flow rates were obtained by opening the sample valve and securing the concentrate return valve. The ultrasonic transducer was end mounted as was RO-2.

d. The common supply from feed or flush tanks was regulated by manual valves at the base of the tanks. The feed went past the temperature well to the self priming strainer pump P-1. This pump strainer was 3/16 mesh to prevent pump and valve plugging. From pump P-1 feed flowed either through a Laval centrifugal type separator or directly into the system. (The separator was removed during the last two months of testing due to the large amounts of iron it put into the system). As air injection line was secured down stream from the separator to allow air feed during the testing. A sample line was secured to the discharge of P-1.

e. Materials were as follows:

(1) Low pressure piping - PVC and polypropylene tubing.

(2) RO-1 high pressure tubing 304 and 316 stainless steel.

(3) RO-2 high pressure pipe 304 stainless steel.

(4) UF piping PVC and 304 stainless steel.

(5) P-1 plastic and stainless steel.

(6) P-2 304 and 316 stainless steel.

(7) P-3, P-4 nickel plated iron and stainless steel.

(8) P-5, P-7, P-6, 304 stainless steel, cast iron pump and motor ends, Moryl plastic impellers and diffusers, 416 stainless steel shaft.

(9) Laval Separator is steel.

(10) Low pressure valves are bronze and PVC.

(11) High pressure valves are bronze and stainless steel.

2. The ultrasonics (GFE) were arranged into two loops, one for RO-1, the second for RO-2 and the UF.

a. The RO-1 ultrasonic system consisted of three fixed frequency ultrasonic generators with Variac input voltage supplies to regulate output power levels. Each generator supplied ultrasound to a set of transducers mounted on one of the RO-1 "U" tubes as shown in Figure 1.

b. The RO-2 and UF ultrasonic system utilized an EIN ultrasonic generator with extended capabilities in frequency and output plus ancillary monitoring and distribution units. This power supply drove the end mounted transducers for both RO-2 and the UF loops.

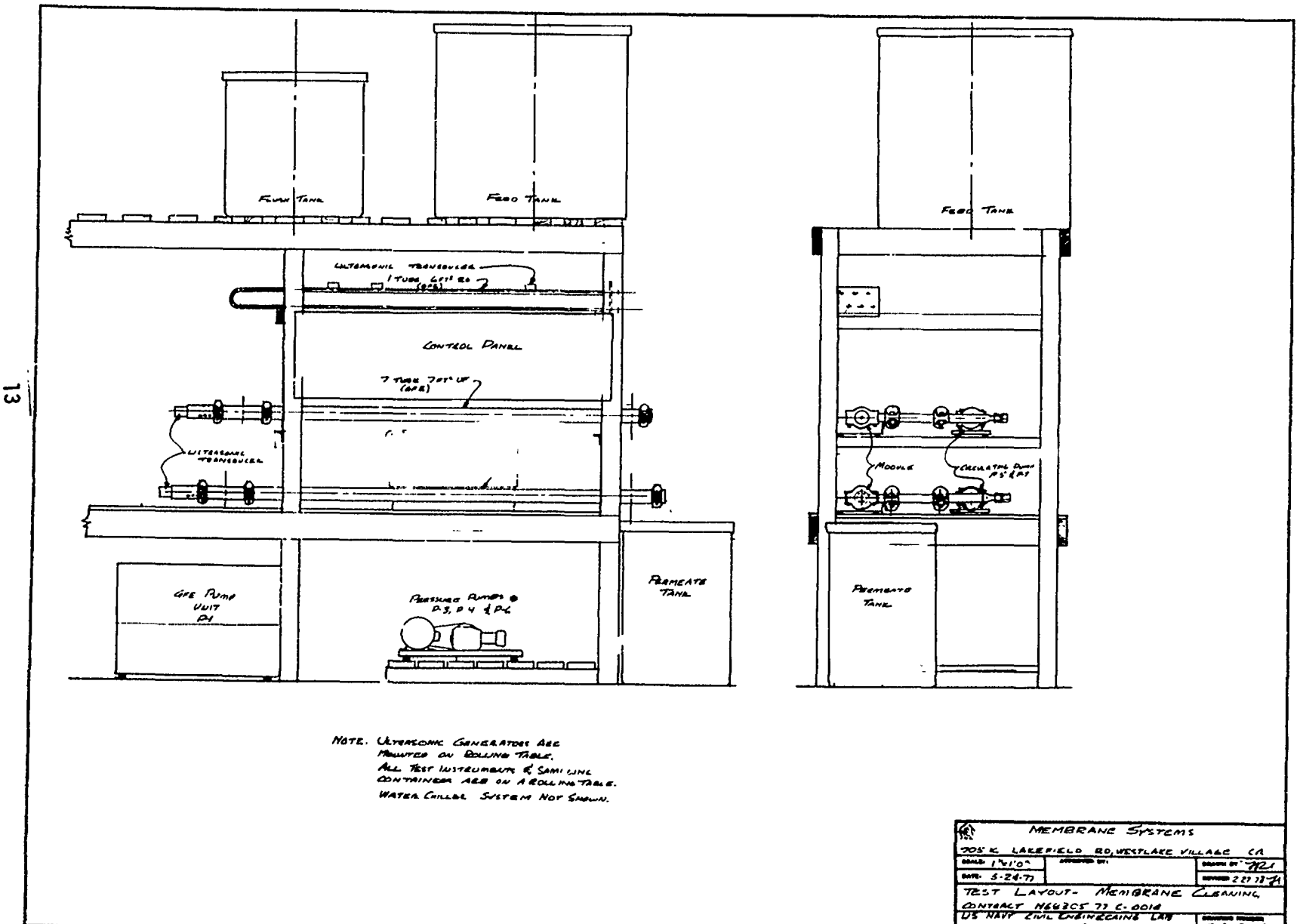
3. Test monitoring equipment included Balsbaugh pH and conductivity monitors, various graduate cylinders and stopwatches. and laboratory thermometers.

The test system was set up April-May of 1977, and checkout started in June. All systems were fully operational in August 1977.

APPENDIX A

FIGURE 1 TEST LAYOUT

FIGURE 2 FLOW DIAGRAM



NOTE. ULTRASONIC GENERATORS ARE MOUNTED ON ROLLING TABLE. ALL TEST INSTRUMENTS & SAMPLING CONTAINERS ARE ON A ROLLING TABLE. WATER CHILLER SYSTEM NOT SHOWN.

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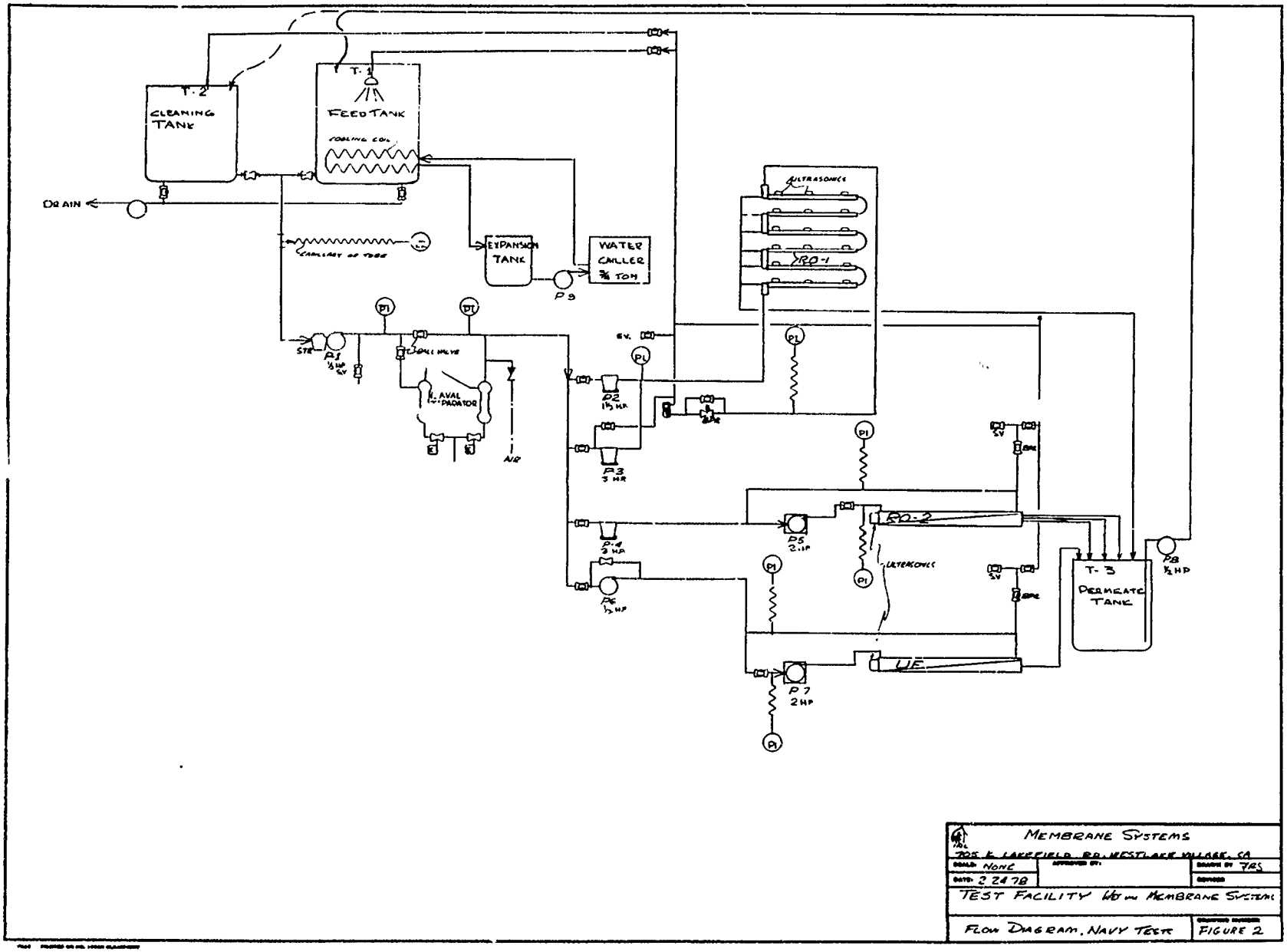
CONTRACT N62C5 77 C-0018	
US NAVY CIVIL ENGINEERING LAB PT HUENEME CA	FIG. PT. 2



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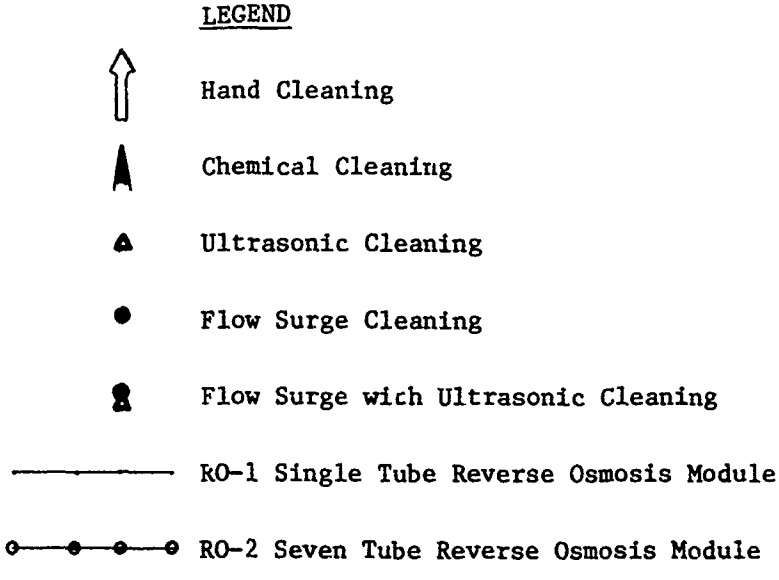
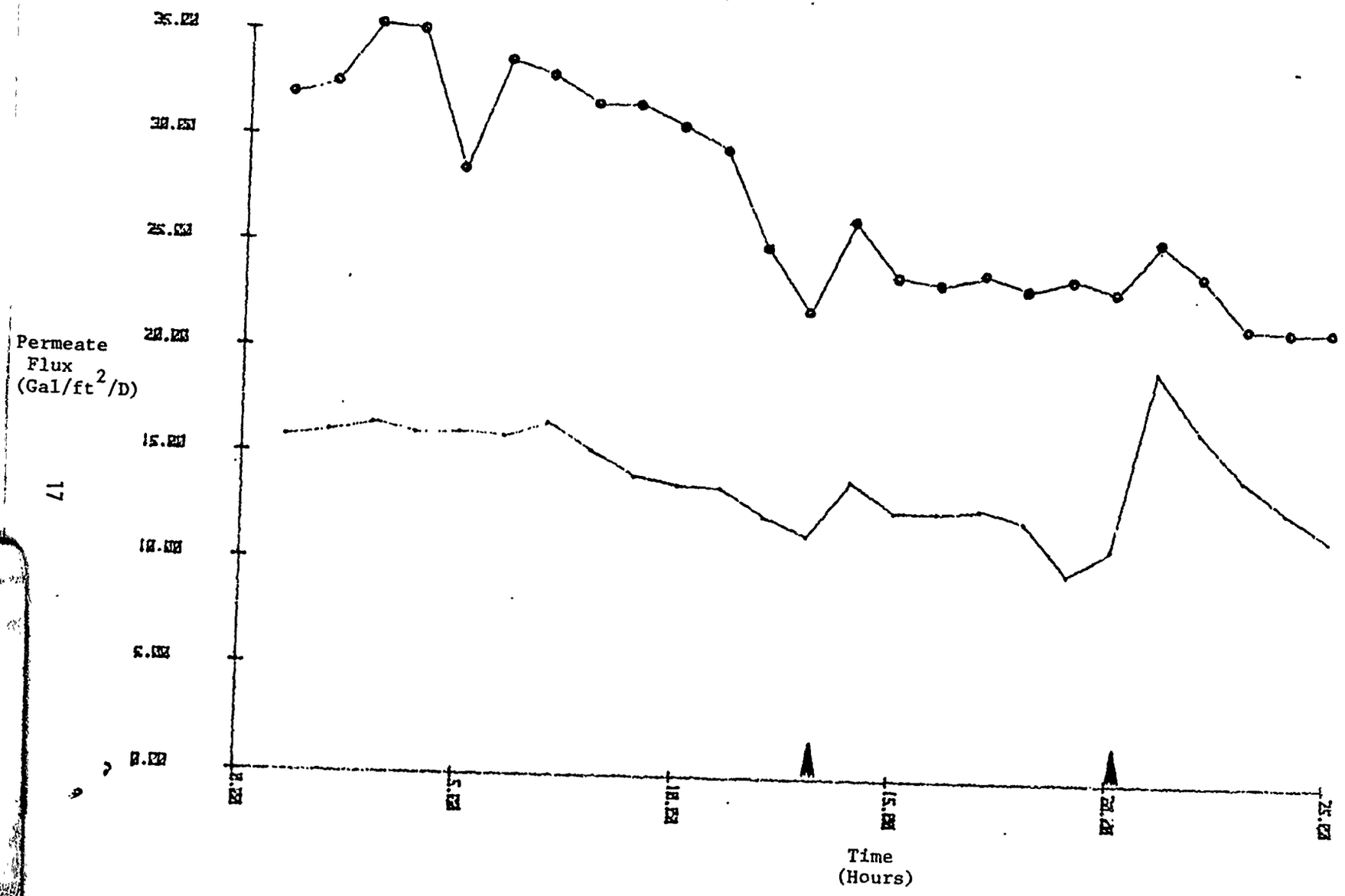
FLOW DIAGRAM, NAVY TESTS		FIGURE 2

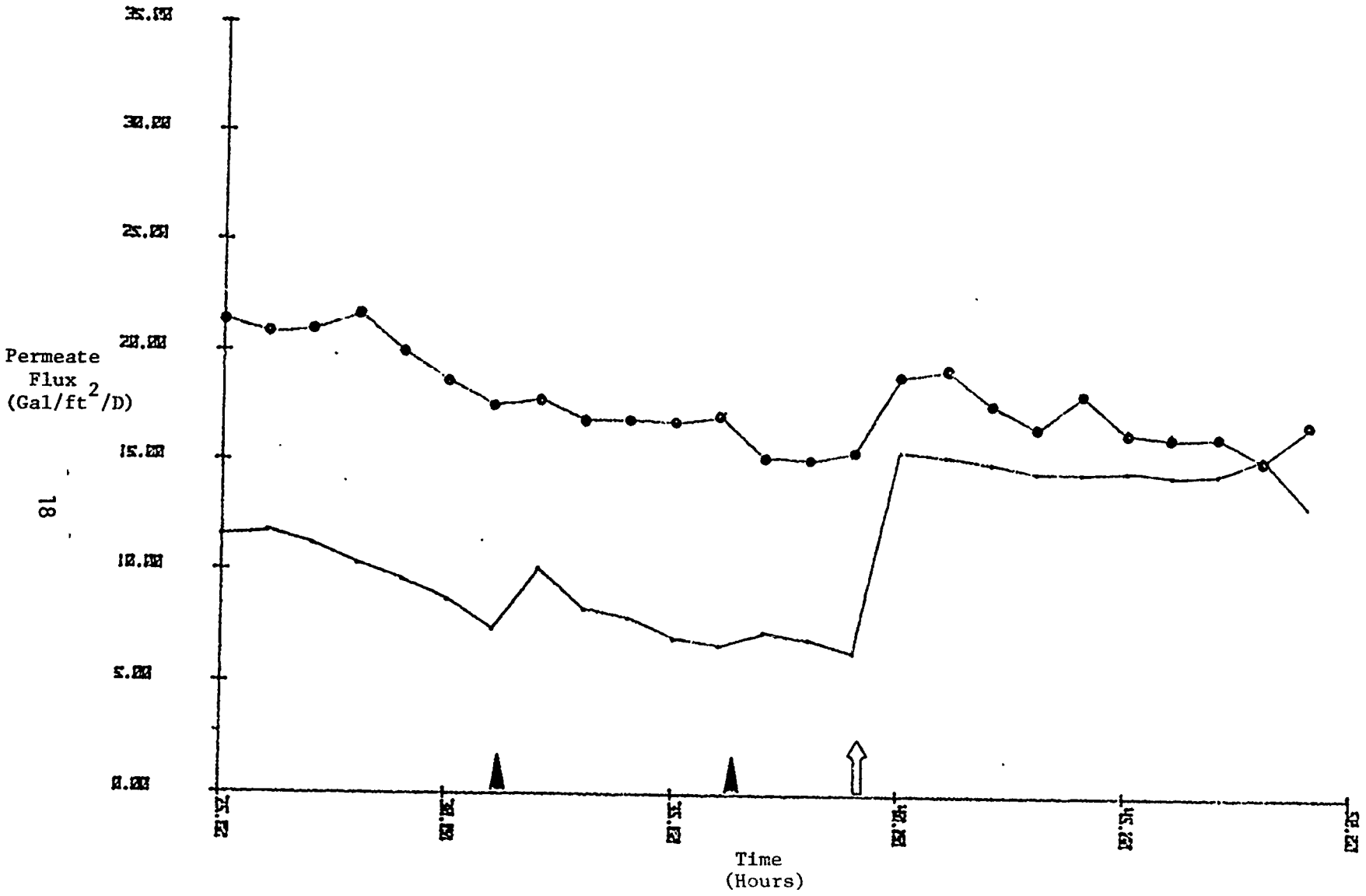
APPENDIX B

TEST DATA GRAPHS

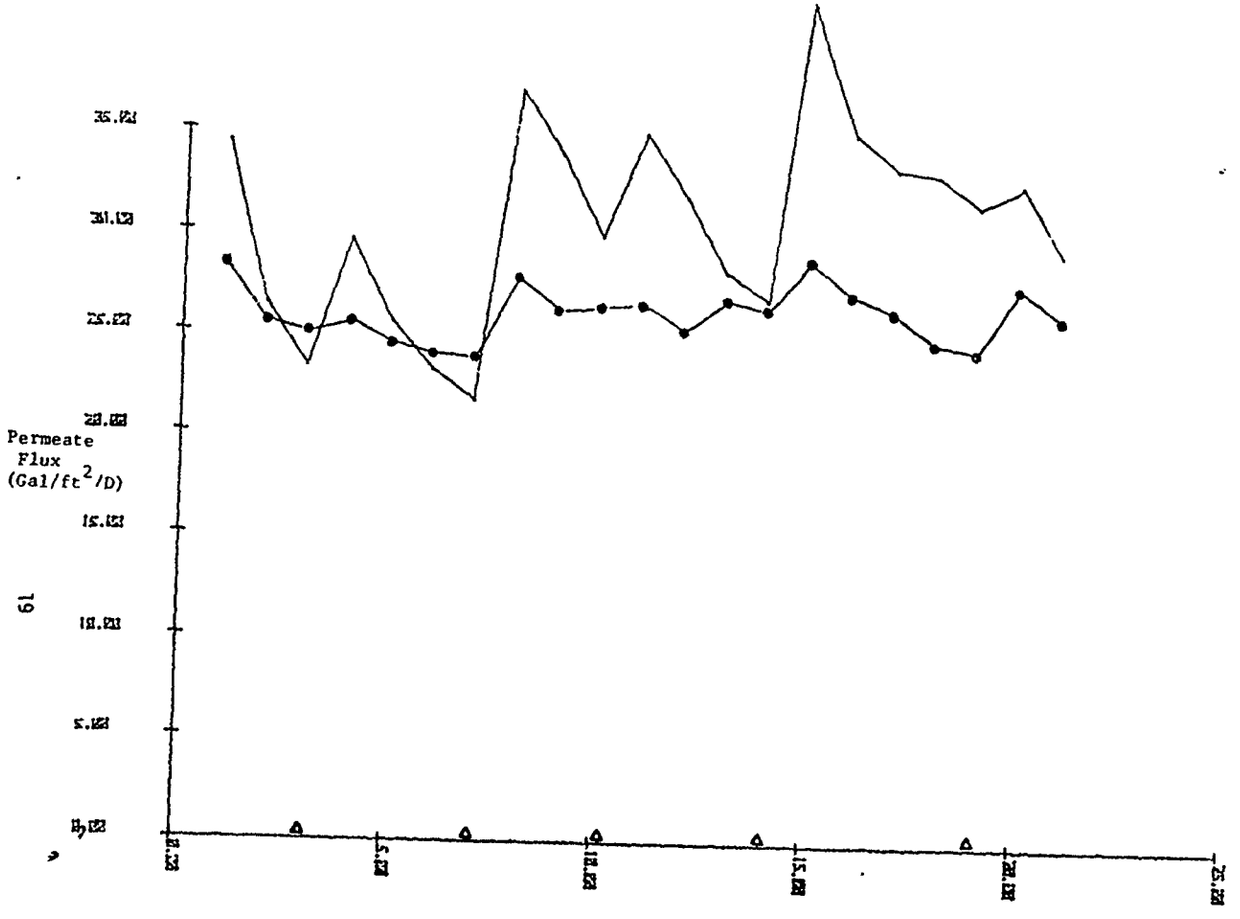




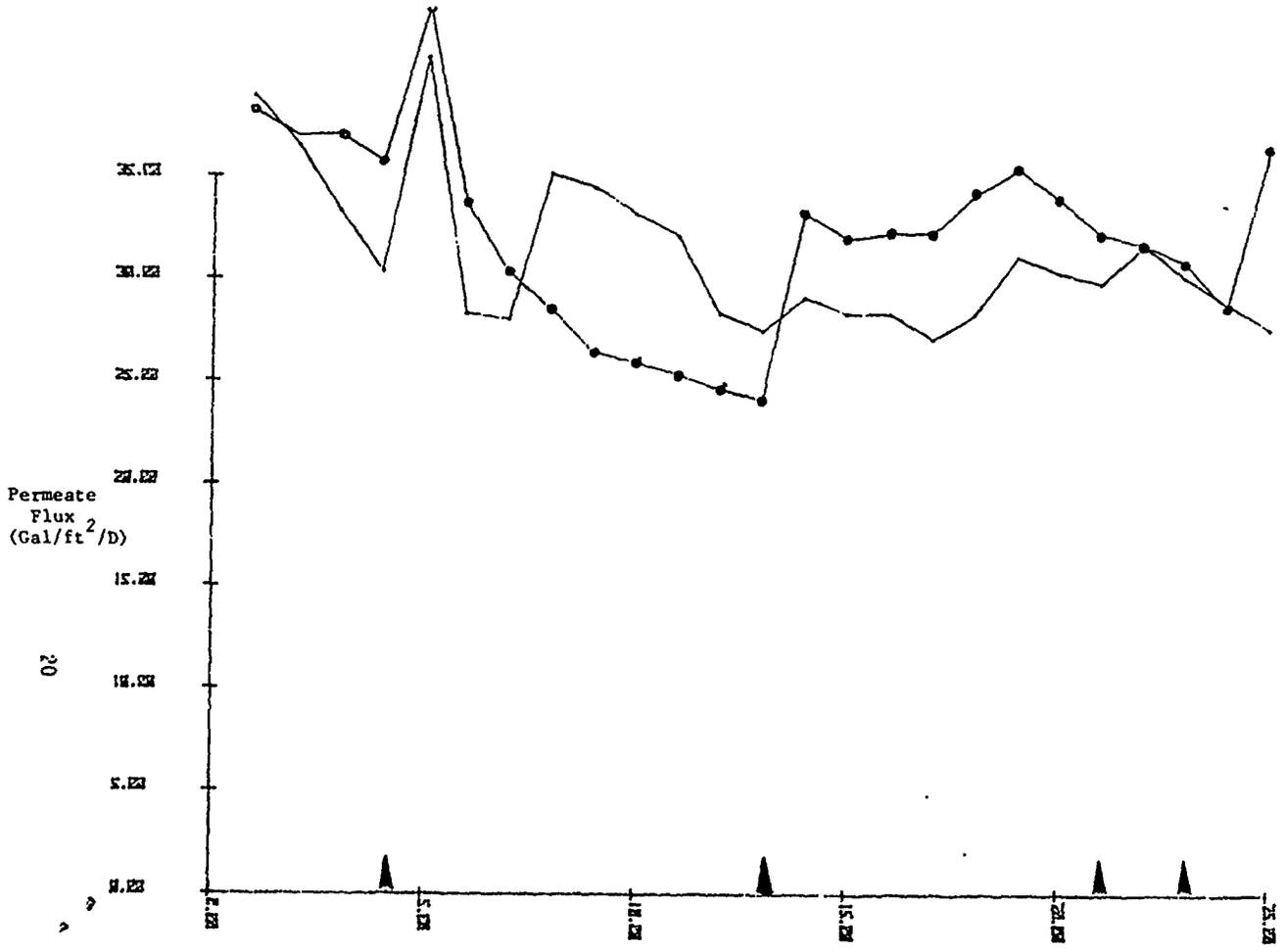
Graph 1A - High Flow Velocity (7 - 9 ft/sec - 600 psi)



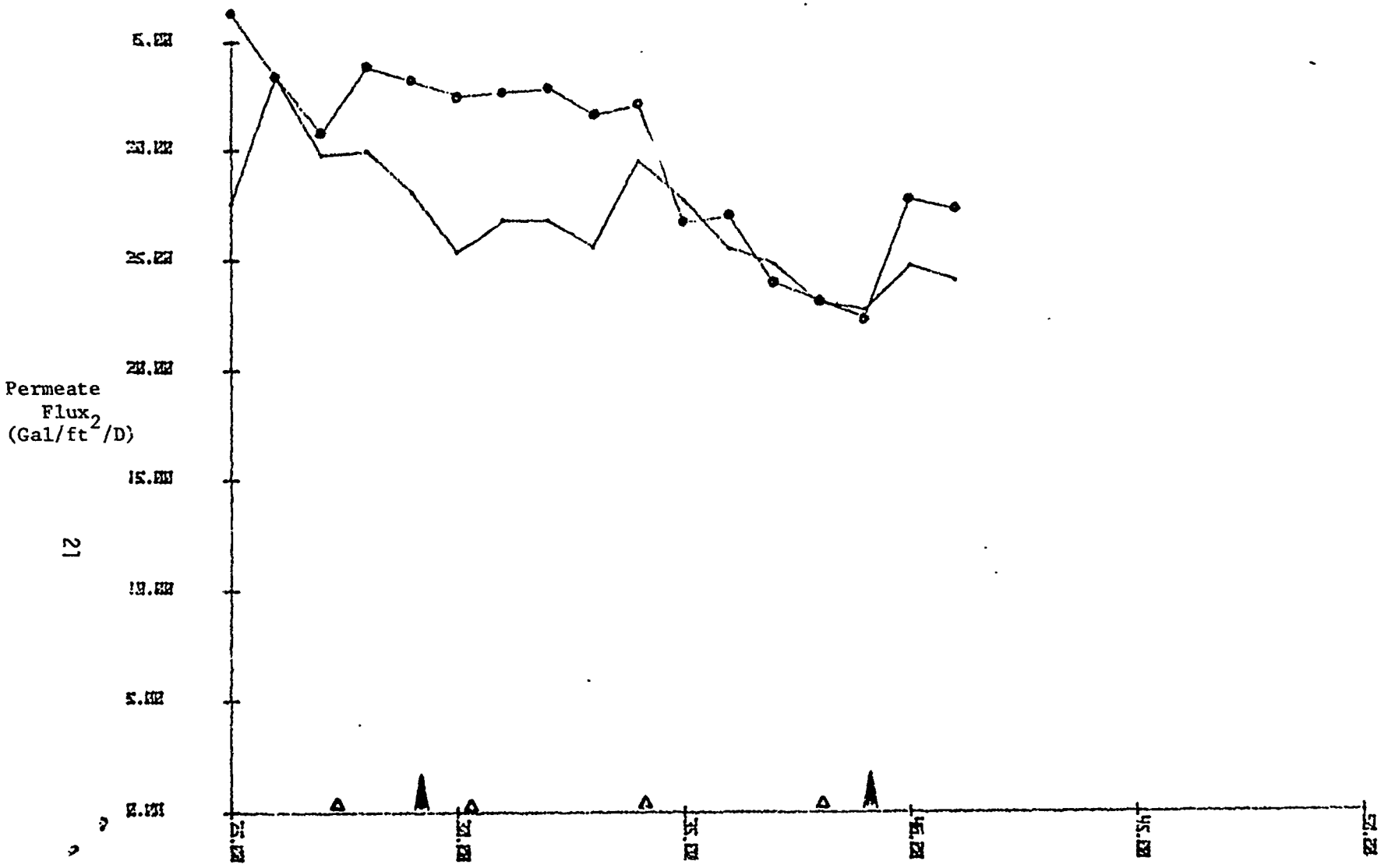
Graph 1B - High Flow Velocity (7 - 9 ft/sec - 600 psi)



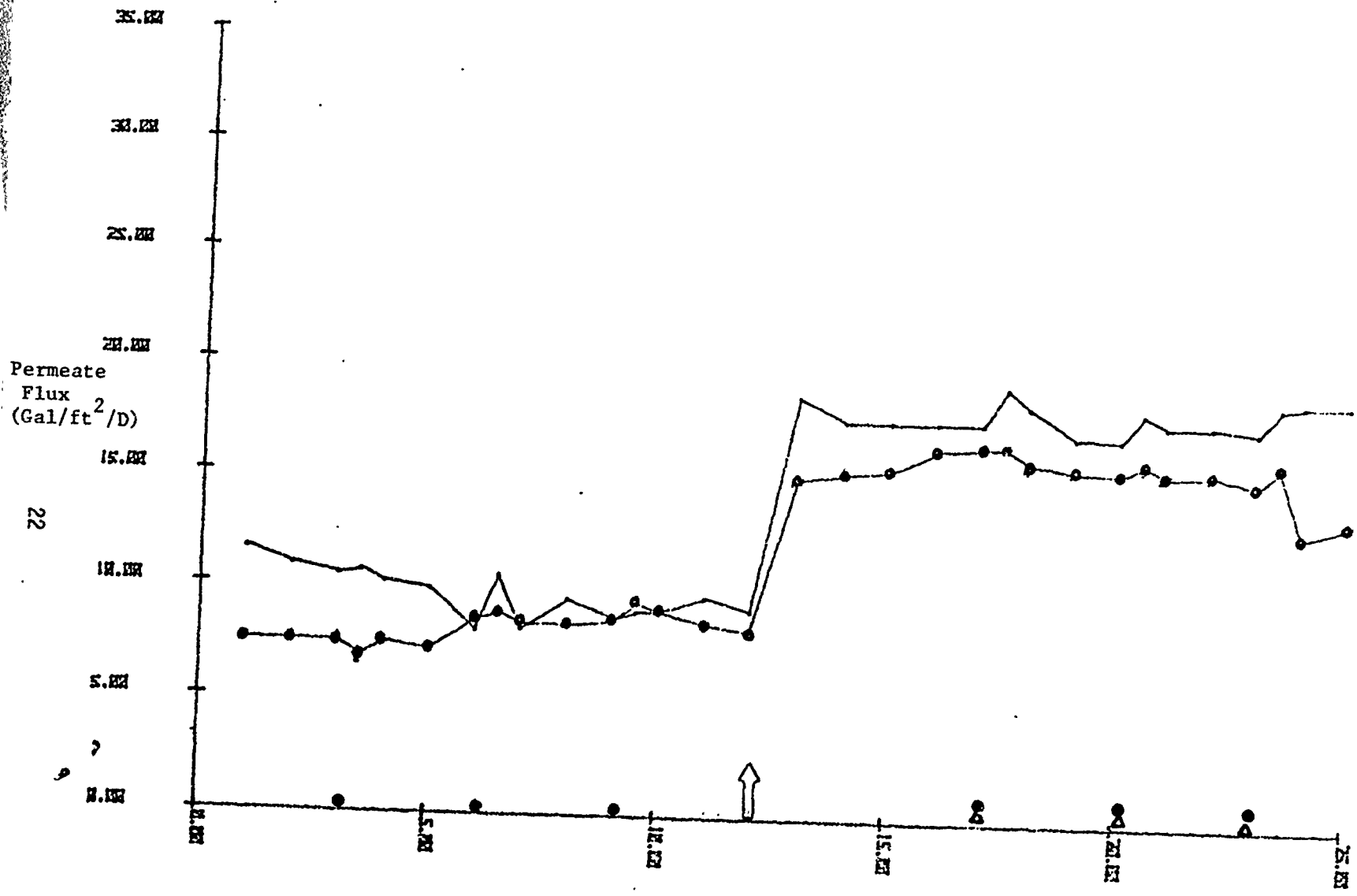
Graph 2 - Ultrasonics (1 - 10 hrs. 0 psi; 11 - 21 hrs. 50 psi)



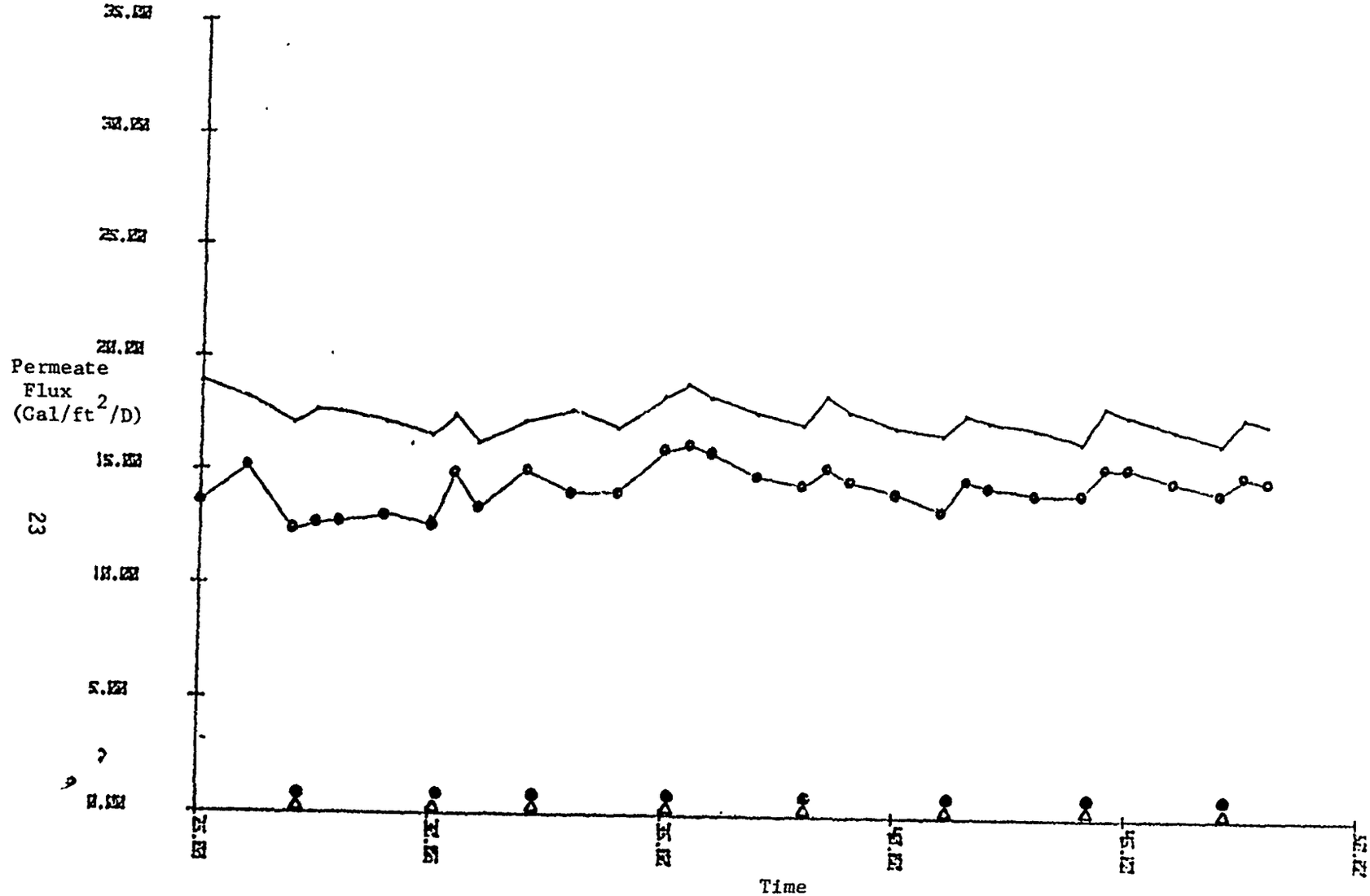
Graph 3A - Continuous Air (300 psi)



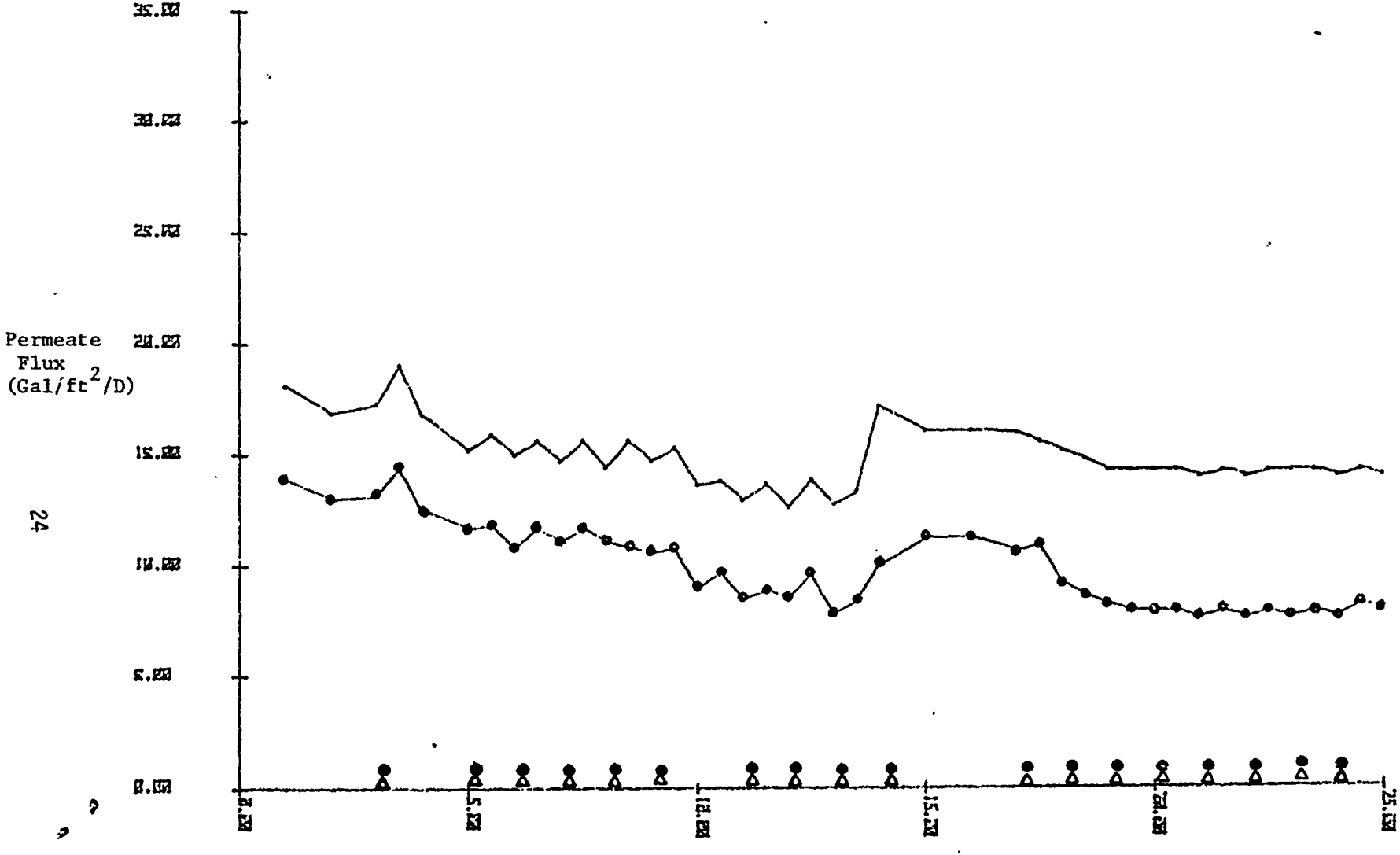
Graph 3B - Continuous Air (300 psi) with ultrasonics (0 psi)



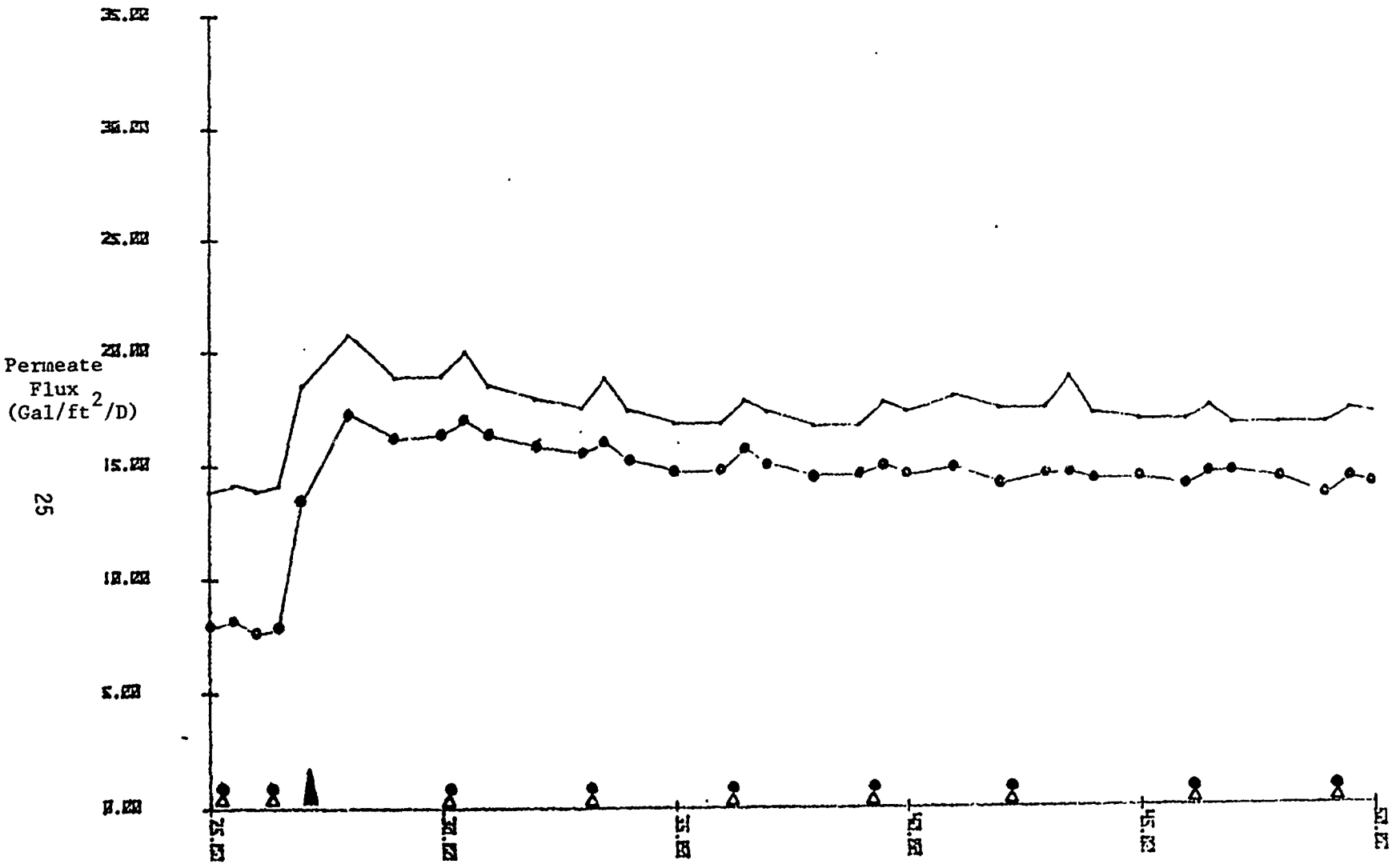
Graph 4A - Flow Surge with/without Ultrasonics (1 - 22 hrs. 50 psi; 22 - 25 hrs. 300 psi)



Graph 4B - Flow Surge with Ultrasonics (25 - 32 hrs. 300 psi; 33 - 48 hrs. 50 psi)



Graph 5A - Flow Surge with Ultrasonics (300 psi)



Graph 5B - Flow Surge with Ultrasonics (25 - 26 hrs. 300 psi; 27 - 50 hrs. 50 psi)

APPENDIX C

TABLES

TABLE I

SUMMARY OF TEST MODE RUNS

TEST MODE		START AVE* GFD	END AVE* GFD	FINAL GFD INITIAL GFD %	REMARKS
Task 1					
Laundry	RO-1	27.9	21.7	78	Baseline, no cleaning
	RO-2	20.6	15.3	74	
	UF	15.5	12.5	81	
Galley	RO-1	30.8	22.6	73	Baseline, no cleaning
	RO-2	19.6	16.3	83	
	UF	17.2	15.8	92	
Shower	RO-1	No test, motor failed			
	RO-2	27.9	27.5	99	Baseline, no cleaning
	UF	27.6	24.9	90	
Composite	RO-1	28.4	24.0	85	Baseline, no cleaning
	RO-2	17.8	11.8	66	
	UF	12.4	9.3	75	
Task 3					
Composite	RO-1	40.6/11.1**	10.3/7.9**	25/71**	Chemical clean
Low	RO-2	28.0/11.4	4.0/ 2.5	14/22	Low flow
	UF	22.9/12.8	10.2/ 12.1	45/95	
Medium	RO-1	33.3/13.0	8.6/6.5	81/50	Chemical clean
	RO-2	19.0/20.2	8.6/14.7	48/73	Medium flow
	UF	13.6/4.0	14.1/23.0	104/+575	
High	RO-1	34.8/14.8	24.7/11.1	71/75	Chemical clean
	RO-2	27.2/32.0	23/21.2	85/66	High flow
	UF	24.5/29.8	17.7/6.0	72/20	
Task 4-5					
Composite	RO-1	38.9	35.5	91	Ultrasonics, RO-1 All flows.
	RO-2	27.7	26.8	97	High flow RO-2
	UF	3.7	3.0	81	
	UF	32.0	15.0	47	New membrane
Composite	RO-1	20.9	12.0	57	Ultrasonics 500 PSI
	RO-2	29.8	12.1	41	" " "
	UF	3.5	6.0	171	Ultrasonics 110 PSI
	RO-1	32.4	15.4	48	Ultrasonics 50 PSI
	RO-2	26.5	16.9	63	
	UF	15.1	5.0	33	

* First two hours average or last two hours average.
** First run low pH= 6.7/6.8, Second run high pH=9.4

TABLE I
cont.

TEST MODE		START AVE GFD	END AVE GFD	FINAL GFD / INITIAL GFD %	REMARKS
Task 8					
Composite	RO-1	26.1	28.0	107	Continuous air & Chemical
	RO-2	31.7	32.6	103	
	UF	9.3	4.7	57	
	RO-1	21.7	13.4	62	Continuous air & US
	RO-2	26.6	18.1	68	@ 0 PSI
	UF	5.0	3.3	66	
	RO-1	37.5	31.6	84	Continuous air
	RO-2	41.9	31.2	74	@ 300 PSI
	UF	10.1	4.5	45	
	RO-1	29.0	18.5	64	Continuous air 300 PSI
	RO-2	33.6	19.3	57	US @ 0 PSI
	UF	4.1	1.4	34	
Task 7					
Composite	RO-1	18.8	7.4	39	Air surge 20 PSI
	RO-2	15.1	3.5	23	(2 hand clean)
	UF	1.6	.5	31	
Task 9					
Composite	RO-1	14.6	9.6	66	Flow surge @ 50 PSI
	RO-2	11.8	8.3	70	
	UF				
	RO-1	18.0	17.5	97	50 PSI flow surge &
	RO-2	16.2	15.8	98	US @ 50 PSI
	UF				
	RO-1	17.4	17.1	98	Flow surge @ 300 PSI
	RO-2	13.5	12.0	89	
	UF				
	RO-1	13.0	11.0	85	Flow surge @ 600 PSI
	RO-2	10.8	8.7	81	
	UF				
	RO-1	16.0	14.0	88	Flow surge @ 300 PSI &
	RO-2	13.3	7.8	59	US
	UF				
Task 7					
Revised	RO-1	19.6	16.1	82	Flow surge 50 PSI &
Composite	RO-2	14.9	10.8	72	US
	RO-1	15.6	9.8	63	US @ 0 PSI
	RO-2	11.8	8.1	69	

TABLE 2

TASK	DESCRIPTION OF TEST MODES	RUN & CLEAN TIME
1	Baseline with no special cleaning A. Baseline- Laundry wastes only 1 B. Baseline- Galley wastes only 1 C. Baseline- Shower wastes only 1 D. Baseline- Composite of Laundry, Galley, & Shower 1 Note 1 : Table shows details of specific streams and composite streams. All subsequent runs were composite waste only.	30 hours
2	Convert to utilize Ultrasonics in tests	—
3	Circulation rates Tests A. 25 GPM RO-2, UF; 3.1 GPM, RO-1, Low flow rates B. 50 GPM RO-2, UF; 3.4 GPM RO-1, medium flow rates C. 71 GPM RO-2, UF; 3.4 GPM RO-1, High flow rates	130 hours
4	Ultrasonics Baseline A. 0 psi, no flow plus Ultrasonics B. 50 GPM @ 50 psi plus US RO-2, UF, 3.4 GPM RO-1 C. 50 GPM @ 550 psi RO-2, 3.4 GPM @550psi RO-1, 50 GPM @ 100 psi UF plus US	136 hours
5	Chemical Baseline, Minimum Pressure	134 hours
6	Three Chemical Analyses- Concurrent with Tasks 3-5	—
7	Air Surge Cleaning A. Air surge @ 0 psi or minimum pressure B. Air surge @ minimum pressure plus US C. Air Surge @ 300 psi D. Flow surge @ 50 psi plus US * E. Ultrasonics @ 0 psi, no flow * * Replace Air Surge Tests	148 hours
8	Continuous Air Flow A. @ 300 psi B. @ 300 psi plus US C. 600 psi D. @ 600 psi plus US	140 hours
9	Flow Surges A. Minimum pressure flow surge B. Minimum pressure plus US C. 300 psi Flow surge D. 300 psi flow surge plus US E. 600 psi flow surge	144 hours
	Test time	862 hours

TABLE 3

COMPOSITION of WASTE STREAMS

	Stream			
	Shower	Laundry	Galley	Composite
Detergent Type 1		433.0	157.5	176.4
Kaolinite	6.2	100.0		34.73
Na_2CO_3		341.0		109.1
Urea	.3	13.6		4.53
Vegetable Cil		136.2	12.5	46.6
Soap	22.5			9.9
NaCl	27.1			11.9
Scouring Powder	32.6		15.8	18.14
Hair Oil	51.0			22.4
Hair Gel	12.1			5.3
Shampoo	1.6			.7
Toothpaste	12.1			5.3
Deoderant	.3			.13
Mouthwash	.6			.26
Grease			8.4	2.0
Dog food			100.0	24.0
Soap Grit			4.4	1.1
Insect Repellant				.2
Water	180 gal.	180 gal.	180 gal.	180 gal.

Ingrediants in grams unless otherwise stated

APPENDIX D

SUMMARY OF FLUX AND REJECTION RATES

DATE	RO-1 % REJ	RO-1 FLUX	RO-2 % REJ	RO-2 FLUX	UF % REJ	UF FLUX
8-1-77 Task 1 Shower	50	49.0	54	27.5	20	24.3
	65	48.6	32	25.0	9	22.1
			55	25.4	18	21.4
			58	25.0	27	20.1
			62	25.0	20	20.1
			65	29.8	0	28.7
8-22-77 Task 1 Laundry	11	29.3	56	21.1	22	16.0
	50	26.6	72	20.2	13	15.0
	41	24.9	72	19.4	17	14.4
	41	20.1	72	16.7	17	13.2
	43	19.3	63	16.7	20	12.1
	43	24.1	63	13.9	20	12.9
	16	32.0	27	20.1	5	20.2

DATE	RO-1 % REJ	RO-1 FLUX	RO-2 % REJ	RO-2 FLUX	UF % REJ	UF FLUX
8-25-77	33	33.4	50	20.7	11	18.5
Task 1 Galley	25	28.2	50	18.4	5	15.9
	28	26.5	50	18.6	4	16.0
	25	25.1	45	17.0	5	15.2
	30	22.7	45	16.4	5	16.1
	30	22.6	45	16.1	5	15.6
	26	34.0	37	26.3	15	16.5
8-26-77	42	27.3	54	20.2	22	13.6
Task 1 Composit	36	29.5	52	15.3	20	11.3
	28	29.7	50	12.6	8	10.4
	25	26.4	54	12.7	17	9.6
	22	23.7	50	11.7	13	9.7
	22	24.4	50	11.9	13	8.8
	20	34.2	45	19.4	0	12.9

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
9-19-77 Task III	43	39.6	46	26.8	14	24.7
	32	41.6	46	29.3	11	21.1
	36	39.6	46	26.8	0	22.7
	36	38.0	46	28.6	0	23.2
	34	37.2	46	27.0	0	22.8
	32	36.7	46	28.0	1	21.8
	30	35.9	45	28.6	1	21.9
	32	36.2	46	26.9	0	18.6
	36	34.7	48	28.2	0	19.6
9-20-77 Task III	39	34.7	50	27.4	7	18.6
	32	33.7	46	26.0	13	18.4
	50	33.0	48	26.7	8	16.9
	33	32.7	51	26.0	3	17.2
	39	32.4	50	25.6	9	15.9
	32	33.3	48	25.8	10	18.0
	38	29.2	50	25.0	8	16.6
	46	31.6	55	24.6	14	16.6
	37	30.2	51	24.6	18	15.5
	44	31.1	54	24.4	14	14.5
	39	27.7	50	21.2	12	17.3
	36	27.0	52	23.2	6	17.0
	36	26.2	49	20.9	10	15.8

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
9-21-77	15	30.8	44	22.9	10	14.5
Task III	24	15.7	44	18.9	15	13.9
	44	15.6	42	17.3	16	11.9
	28	11.8	51	18.6	14	13.0
	17	10.2	53	13.8	17	12.7
	12	5.9	50	13.6	14	12.6
	8	4.5	48	8.2	9	12.1
	52	8.2	44	17.3	8	16.2
	52	6.5	44	10.3	15	13.9
	59	5.8	44	10.8	15	12.7
	52	5.1	48	7.8	15	13.5
	46	7.9	46	13.4	4	13.4
	50	7.6	48	12.2	4	12.2
	52	7.4	48	9.2	14	12.5
	50	7.25	43	10.2	11	12.1
	48	8.0	46	9.3	10	11.7
	50	8.0	46	10.2	10	11.6
	50	7.4	46	9.57	4	11.4
	50	7.1	46	9.36	4	11.1
	50	7.2	46	8.7	4	10.6

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
9-22-77	54	12.7	38	14.25	4	12.8
Task III	63	10.4	50	12.3	20	11.8
	61	9.1	44	9.6	15	11.0
	61	9.1	48	9.3	11	10.9
	59	9.4	50	8.9	4	10.3
	56	7.7	52	7.6	8	10.1
	75	8.2	50	4.1	12	10.1
	63	9.3	50	5.2	10	10.1
	50	11.3	50	2.7	11	10.3
9-27-77	40	15.8	25	32.0	13	28.3
Task III	45	16.1	27	32.6	10	27.5
	40	16.5	21	35.3	6	27.3
	43	16.0	28	35.1	15	27.2
	47	16.1	31	28.5	22	22.3
	51	15.9	36	33.7	28	19.2
	42	16.6	16	33.0	7	19.2
	44	15.3	29	31.7	9	19.3
	43	14.1	27	31.7	3	19.3
	44	13.7	22	30.7	3	18.4

	RO-1		RO-2		UF	
DATE	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
9-28-77	46	13.6	24	29.6	5	17.8
Task III	42	12.3	26	25.0	11	11.1
	41	11.4	23	22.0	3	10.6
	37	14.0	24	26.3	5	13.8
	43	12.6	31	23.7	10	12.1
	40	12.6	31	23.4	17	11.3
	49	12.8	38	23.9	21	9.7
	40	12.2	25	23.2	12	6.9
	51	9.8	37	23.8	45	6.5
	48	11.0	29	23.1	14	5.3
	34	19.4	18	25.5	21	4.0
	41	16.6	29	23.9	29	4.3
	33	14.4	24	21.5	23	4.0
	34	12.9	20	21.4	20	4.1
	38	11.6	22	21.4	16	4.1
	38	11.8	16	20.8	16	4.1
	47	11.2	18	21.0	18	4.0
	40	10.3	18	21.7	13	3.8
	41	9.6	21	20.0	18	3.6

	RO-1		RO-2		UF	
DATE	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
9-29-77	41	8.7	18	18.7	15	3.0
Task III	43	7.4	20	17.6	10	2.6
	39	10.1	20	17.9	34	2.5
	44	8.3	12	16.9	10	2.5
	46	7.9	12	16.9	12	2.4
	44	7.0	19	16.8	12	2.3
	44	6.7	18	17.1	18	2.5
	48	7.3	20	15.2	18	2.1
	19	7.0	14	15.1	14	2.0
	23	6.4	25	15.5	23	2.0
	44	15.5	11	19.0	4	3.8
	44	15.3	14	19.3	16	3.2
	46	15.0	19	17.7	18	3.1
	43	14.6	18	16.6	15	3.0
	49	14.6	21	18.2	15	2.9
	41	14.7	15	16.4	11	2.8
	45	14.5	11	16.2	4	2.8
	46	14.6	14	16.3	--	---
	46	15.4	14	15.2		
	45	13.2	17	16.8		
9-30-77	48	13.0	21	16.3		
	38	12.8	17	14.9		

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
11-4-77	75	21.7	79	30.5	18	3.6
Task IV, V US 500 psi	75	20.1	79	29.1	18	3.5
	76	21.1	79	25.1	17	3.6
	81	19.7	55	26.6	13	3.6
	81	18.7	77	26.4	19	3.4
	80	17.7	77	26.0	17	3.3
11-9-77	77	25.8	77	31.1	31	3.4
Task IV, V US 500 psi	79	31.1	79	32.0	21	4.0
	79	28.9	79	31.2	18	3.6

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
11-10-77	78	25.2	81	28.2	23	3.1
Task IV, V US 500 psi	77	27.1	81	26.9	13	3.6
	77	20.2	76	23.6	17	3.5
	89	16.8	89	23.5	23	3.5
	89	13.1	95	22.0	23	3.1
	86	34.0	91	26.7	10	3.2
	90	30.5	93	26.8	28	3.1
	91	28.8	93	25.9	30	3.2
	91	27.4	94	24.9	28	3.1
	72	27.6	72	22.9	0	3.0
	81	29.2	81	23.8	13	3.3
	90	28.2	94	23.2	13	3.3
	81	24.9	81	22.2	16	3.1
	81	23.6	81	21.2	13	3.3
	82	21.9	82	20.8	13	3.1
	77	27.7	81	21.2	16	3.3
	81	25.8	81	20.4	13	3.0

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
11-15-77	61	40.0	70	37.3	9	4.3
Task IV,V US Opsi	72	37.8	79	27.7	18	3.1
	76	33.8	76	26.6	15	2.9
	78	32.5	74	31.2	15	3.0
	76	28.9	73	28.3	13	3.2
	78	27.0	79	27.3	20	3.1
	79	23.6	77	25.6	18	2.8
	76	23.4	79	25.7	18	3.2
	80	21.9	80	24.4	23	3.0
	78	20.6	78	23.5	15	3.1
	78	20.3	78	23.1	15	3.1
	76	20.3	79	22.8	18	3.0
	76	19.9	79	23.3	18	2.9
	76	25.5	79	30.2	18	3.2
	76	25.1	79	29.8	18	3.2
	76	42.0	79	30.7	14	3.4
	75	37.5	79	30.8	14	3.1
	75	34.1	79	29.7	11	3.0
	75	32.4	79	28.9	14	3.2
	77	31.0	81	28.1	20	3.0
	79	27.7	81	26.5	16	3.0
	79	25.3	80	25.9	21	3.0

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
11-18-77	75	32.8	78	30.1	4	31.9
Task IV, V US 0psi	79	33.0	79	29.6	4	32.1
	74	31.8	78	29.0	0	30.4
	79	27.5	79	27.1	0	25.7
	47	50.9	71	40.6	9	32.0
	61	39.3	79	31.2	0	30.5
	77	35.7	80	30.1	10	27.1
	77	30.9	80	29.5	10	27.1
	77	27.0	81	27.6	10	18.3
	77	26.2	67	26.6	13	17.9
	67	32.5	67	29.1	10	20.5
	77	30.8	81	27.6	10	20.0
	75	33.3	79	29.1	4	23.7
11-21-77	75	34.4	79	28.3	2	22.4
Task IV, V US 0psi	75	26.4	79	25.5	4	20.1
	75	23.3	79	25.0	4	18.4
	74	29.6	77	25.6	4	17.2
	76	25.6	79	24.5	7	16.1
	77	23.2	81	24.0	13	15.6
	77	21.7	81	23.8	13	14.8
	76	37.1	79	27.8	7	14.1
	77	33.9	80	26.2	10	15.6

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
11-22-77	78	29.9	75	26.4	5	14.7
Task IV, V US 50psi	65	35.0	80	26.6	10	15.5
	79	31.9	79	25.3	6	14.5
	81	28.2	80	26.8	16	13.8
	80	26.8	81	26.3	12	13.2
	64	41.4	78	28.9	4	16.3
	80	35.1	80	27.1	10	14.1
	81	33.4	81	26.3	16	13.6
	78	33.1	81	24.8	13	13.3
11-23-77	81	31.6	81	24.4	13	16.0
Task IV,V US 50 psi	65	32.7	81	27.6	3	15.9
	77	29.3	81	26.1	3	14.2
11-28-77	74	33.2	78	27.6	4	17.8
Task IV, V US 50 psi	73	36.0	77	28.2	12	16.0
	78	23.2	83	24.4	5	14.0
	71	17.4	76	22.5	0	12.6
	80	16.0	84	32.5	2	12.7
	78	13.6	87	19.2	8	12.1
	63	17.7	78	19.4	0	11.6

	RO-1		RO-2		UF	
ATE	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
11-29-77	78	15.6	80	16.9	7	9.4
Task IV, V US 50 psi	92	16.4	87	18.9	54	10.5
	56	19.4	78	20.3	6	9.5
	78	16.7	88	20.1	9	9.8
	78	14.7	87	17.4	4	9.0
	64	16.9	79	18.7	14	7.0
	79	15.2	89	15.0	7	8.9
	79	14.3	89	14.5	7	8.3
	59	16.4	78	18.2	5	8.3
	93	13.9	88	16.1	14	8.3
11-30-77	54	22.7	78	19.5	7	6.8
Task IV, V US 50 psi	79	20.0	86	16.3	14	4.8
	78	19.9	87	17.3	16	4.9
	66	20.4	79	19.5	14	5.4
	80	20.0	87	17.8	17	4.8
	81	18.8	87	17.6	13	5.0
	67	19.7	79	17.9	13	4.9
	81	17.3	88	18.1	15	5.0
	68	19.6	81	18.5	16	4.9
	81	17.2	89	17.2	18	5.2
	81	15.9	89	17.2	16	5.4
12-1-77	79	16.8	87	17.8	6	5.7
Task IV, V US 50 psi	75	13.9	79	15.0	6	5.0
	63	15.5	78	16.6	6	5.0
	63	15.2	74	16.9	6	5.1

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
12-20-77	65	32.2	79	36.8	10	9.8
Task VII Continuous Air 600 psi	77	20.0	78	26.6	10	8.8
	79	20.8	78	26.3	9	8.2
	93	15.6	87	23.2	8	7.3
	88	13.3	83	21.7	9	7.7
	86	12.4	86	25.4	6	5.1
	88	12.1	87	25.4	8	7.0
	89	10.8	83	24.4	6	4.6
	90	10.5	85	23.1	8	6.7
	92	28.1	87	33.8	8	6.3
	94	25.4	89	33.1	7	5.6
12-2-77	78	13.8	78	15.5	11	5.2
Task IV,V US 500 psi	79	14.7	79	15.2	18	5.1
	62	20.9	78	18.7	13	5.1
	78	13.7	78	16.1	13	5.1
	79	12.9	79	15.3	18	5.1
	79	12.7	79	15.0	15	5.9
	78	12.1	78	13.7	14	6.0
	75	12.5	79	13.8	7	6.1
	78	11.5	78	10.4	--	---

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
12-21-77	93	27.1	86	35.8	18	7.4
Task VIII	94	23.9	87	32.6	12	4.2
Continuous Air	95	23.6	88	29.9	21	4.3
600 psi	95	21.0	88	28.1	18	4.0
	82	19.2	79	25.3	9	5.4
	86	28.6	80	36.2	4	5.1
	83	26.7	81	32.3	14	4.9
	83	26.4	80	29.8	11	5.3
	83	27.2	81	31.8	19	5.3
	83	26.4	80	31.0	23	5.1
	83	25.6	80	30.4	23	4.8
	83	24.3	80	29.8	20	4.6
	83	23.9	80	28.7	20	4.5
	81	29.1	78	33.8	22	5.3
	83	28.4	80	33.2	23	4.9
	83	27.7	80	32.1	23	4.4
12-22-77	88	25.5	81	29.1	19	5.1
Task VII	85	18.1	78	24.1	19	5.0
Continuous Air	89	13.1	74	20.1	19	4.7
600 psi	81	16.7	81	29.3	16	5.0
US 0 psi	79	14.6	79	27.8	7	3.7
	78	19.7	74	29.4	4	4.7
	84	18.1	81	29.6	23	4.8
	83	16.9	80	29.1	21	4.6

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
12-23-77	81	19.8	81	30.9	13	4.9
Task VIII Continuous Air 600 psi US 0 psi	84	18.0	81	29.9	16	4.6
	81	17.8	81	28.5	16	4.6
	81	20.3	81	31.9	13	4.4
	84	19.5	77	31.3	13	4.4
	84	18.9	77	30.6	13	4.1
	84	18.4	81	28.9	16	3.8
12-27-77	73	21.5	77	33.2	23	4.2
Task VIII Continuous Air 600 psi US 0 psi	74	19.9	78	32.9	26	4.1
	75	18.2	79	30.6	26	3.2
	75	16.6	79	28.5	18	3.1
	74	25.5	78	33.8	41	3.8
	75	22.7	79	30.6	11	4.1
12-28-77	79	23.6	75	31.5	18	2.8
Task VIII Continuous Air 600 psi US 0 psi	78	24.2	74	32.2	0	2.5
	81	22.3	78	30.9	53	3.9
	81	19.6	81	29.0	0	3.8
	81	17.6	81	25.8	0	3.5
	81	16.7	78	25.1	13	3.7
	81	15.5	77	22.8	32	3.2
	81	15.4	77	22.6	23	3.6

	RO-1		RO-2		UF	
TE	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
12-29-77	78	17.0	74	19.8	22	3.5
Task VIII Continuous Air 600 psi US 0 psi	78	18.6	74	21.3	25	3.1
	79	14.2	79	19.4	22	3.2
	80	12.1	77	18.7	0	3.4
	80	15.0	77	19.9	10	3.5
	80	11.7	77	16.3	3	3.1
1-3-78	77	38.6	81	43.9	10	10.2
Task VIII Continuous Air 300 psi	81	36.5	81	40.0	13	9.9
	81	33.3	81	40.0	13	8.8
	81	30.4	78	35.7	13	9.0
	77	44.2	81	54.5	13	9.6
	78	28.3	78	33.7	13	8.5
	81	28.0	78	30.3	13	7.4
1-4-78	77	35.1	77	28.5	16	6.9
Task VIII Continuous Air 300 psi	77	34.5	77	26.4	13	6.3
	77	33.2	77	25.9	13	6.4
	77	32.1	77	25.3	13	6.2
	77	28.3	77	24.6	13	5.7
	82	27.5	79	24.1	18	5.5
	78	29.1	78	33.2	13	6.0
	80	28.3	80	32.0	20	6.1
	79	28.3	79	32.3	6	5.8
	79	27.1	79	32.3	21	6.1
	79	28.3	79	34.2	8	5.8

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
1-5-78 Task VIII Continuous Air 300 psi	77	31.1	77	35.4	10	5.4
	80	30.3	80	33.9	10	5.1
	77	29.8	77	32.2	13	5.2
	77	31.7	81	31.7	10	5.3
	81	30.1	81	30.8	13	
	81	28.8	81	28.6	13	5.0
	77	27.6	77	36.3	13	5.4
	81	33.4	77	33.4	10	5.6
	81	29.8	77	30.8	7	5.5
6-78 Task VIII Continuous Air 300 psi US 0 psi	82	30.0	82	33.8	6	5.9
	80	28.1	80	33.2	6	5.6
	83	25.4	83	32.5	5	4.7
	83	26.8	83	32.7	5	4.6
	83	26.8	83	32.9	6	5.2
	82	25.6	82	31.6	6	4.7
	82	29.5	82	32.1	5	4.3
	80	27.7	81	26.7	14	4.0
	80	25.5	82	27.0	8	4.2
	82	24.8	83	23.9	13	4.6
	81	23.0	83	23.1	12	4.2
	83	22.7	85	22.3	9	4.3
	83	24.7	83	27.7	19	4.4
	83	24.0	83	27.2	17	4.4

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
1-9-78	75	24.1	75	22.9	4	3.9
Task VIII	75	23.3	75	21.6	4	3.5
Continuous Air	74	22.6	74	21.0	4	3.4
300 psi	74	22.6	74	18.9	4	3.6
US 0 psi	66	27.5	79	24.7	2	1.8
	77	23.3	79	21.5	2	1.8
	78	21.4	80	20.4	2	1.9
	78	19.2	78	18.2	2	1.8
	79	19.3	81	[illegible]		1.8
	79	18.4	81	1[illegible]		1.6
	75	21.0	75	20	2	1.4
	75	19.4	75	20.2	2	1.4
	78	17.5	78	18.3	2	1.4
1-16-78	26	17.4	26	13.5		
Task IX	78	13.8	74	12.1		
Flow Surge	79	11.6	77	12.7		
50 psi	77	14.4	76	12.7		
	78	11.2	73	11.3		
	81	9.6	76	10.5		
	81	9.0	74	9.7		
	81	7.0	74	8.9		
	81	7.1	78	8.4		
	81	9.1	78	9.5		
	81	7.9	78	9.1		
	81	7.0	78	8.6		
	81	9.3	78	9.3		

DATE	RO-1 % REJ	RO-1 FLUX	RO-2 % REJ	RO-2 FLUX	UF % REJ	UF FLUX
1-10-78	81	18.8	72	16.5	28	1.8
Task VII Air Surge	79	18.9	74	13.5	30	1.4
	77	19.1	77	15.0	11	1.1
	80	22.2	80	25.1	11	1.5
	82	21.7	82	24.2	16	1.5
1-11-78	81	23.1	81	24.3	9	.90
Task VII Air Surge	81	20.1	81	23.5	8	1.25
	83	17.7	83	21.4	14	1.11
	85	19.0	85	21.0	18	1.13
	84	21.5	83	19.[illegible]	[illegible]	1.15
	85	17.6	82	16.2	21	1.19
	85	16.2	83	11.6	15	1.14
	85	12.5	78	9.7	13	1.14
	86	15.5	80	11.0	27	1.14
	85	13.9	83	8.7	28	1.06
	84	14.8	74	9.6	18	1.06
	83	13.1	75	9.0	20	.79
	83	13.9	69	11.0	16	.79
	77	11.6	63	8.2	0	.75
	79	11.9	51	9.6	0	.75
	85	10.4	75	7.2	23	.75
	84	10.0	65	8.6	19	.75
	84	8.2	65	7.0	12	.75
	84	10.6	66	8.1	19	.74
	84	8.9	74	6.2	17	.78
	83	9.3	66	7.8	13	.70

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
1-12-78	73	12.3	63	9.4	5	.64
Task VII Air Surge	74	10.9	92	6.5	18	.74
	85	12.0	62	7.4	18	.65
	85	10.0	67	6.2	21	.74
	82	11.8	67	6.7	21	.78
	85	9.8	67	5.5	21	.78
	85	11.3	62	6.0	21	.83
	81	10.5	63	5.9	11	.80
	82	11.4	64	6.9	15	.71
	82	9.9	54	4.9	13	.66
	85	8.7	62	4.9	11	.66
	78	8.6	67	4.7	27	.69
1-13-78	78	12.1	37	5.9	0	.69
Task VII Air Surge	75	9.6	43	5.9	0	.54
	77	8.1	44	5.3	0	.52
	77	7.0	66	4.8	3	.46
	81	8.3	52	4.1	13	.52
	73	8.9	24	3.1	22	.36
	84	7.3	39	3.2	20	.48
	83	7.4	56	3.6	17	.47
	55	18.8	29	15.7	14	.21
	84	17.7	78	14.3	22	.31

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
1-17-78 Task IX Flow Surge 600 psi	81	13.3	74	10.1		
	78	14.7	71	11.3		
	81	13.1	78	11.5		
	81	12.2	74	9.5		
	82	11.1	72	9.0		
	82	11.1	72	10.2		
	82	11.9	69	10.4		
	79	11.3	69	8.6		
	78	10.7	69	7.2		
	80	11.5	71	9.6		
	69	10.8	75	9.3		
	78	11.3	72	9.3		
	81	11.3	82	9.3		
	81	11.1	71	8.6		
	81	10.3	69	8.6		
	63	10.4	53	9.1		
	74	11.0	61	9.2		
	75	11.1	69	8.0		
	81	10.0	72	7.4		
	81	9.6	72	7.4		
	81	10.6	72	8.5		
	81	10.9	72	8.8		
	81	10.6	72	8.2		

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
1-18-78	88	11.6	90	7.5		
Task IX Flow Surge 50 psi	80	10.9	67	7.5		
	84	10.5	68	7.5		
	81	10.7	61	6.9		
	84	10.2	66	7.5		
	80	9.9	67	7.2		
	81	8.1	69	8.6		
	81	10.5	69	8.9		
	81	8.2	68	8.4		
	82	9.5	68	8.4		
	81	8.7	68	8.6		
	81	9.0	68	9.4		
	81	9.1	68	9.0		
	81	9.7	68	8.5		
	81	9.1	68	8.2		

DATE	RO-1 % REJ	RO-1 FLUX	RO-2 % REJ	RO-2 FLUX	UF % REJ	UF FLUX
1-19-78	57	18.7	57	15.1		
Task IX Flow Surge 50 psi w US	81	17.7	81	15.4		
	82	17.7	82	15.6		
	80	17.7	80	16.5		
	81	17.7	81	16.7		
	80	19.3	80	16.7		
	82	18.5	82	16.0		
	83	17.2	82	15.7		
	83	17.1	82	15.6		
	82	18.3	81	16.1		
	82	17.8	82	15.6		
	83	17.8	83	15.7		
1-19-78	82	17.6	80	15.2		
Task IX Flow Surge 300 psi	83	18.7	80	16.1		
	82	18.9	82	13.0		
	82	18.9	82	13.6		
	83	18.2	83	15.2		
	82	17.1	82	12.4		
	82	17.7	83	12.7		
	82	17.6	83	12.8		
	83	17.2	83	13.1		
	83	16.6	82	12.6		
	83	17.5	82	14.9		
	83	16.3	82	13.4		

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
1-20-78 Task IX Flow Surge 50 psi w US	80	17.3	77	15.1		
	79	17.8	79	14.1		
	81	17.0	81	14.2		
	83	18.4	80	16.0		
	83	19.0	80	16.3		
	83	18.4	83	15.9		
	83	17.7	83	14.9		
	83	17.2	83	14.5		
	83	18.5	83	15.3		
	83	17.8	83	14.7		
	83	17.1	83	14.2		
	83	16.8	83	13.4		
	83	17.7	83	14.8		
	83	17.4	79	14.5		
	83	17.1	79	14.2		
	83	16.5	79	14.2		
	83	18.1	79	15.4		
	83	17.7	79	15.4		
	83	17.1	79	14.8		
	83	16.5	79	14.3		
	83	17.7	79	15.1		
	83	17.4	79	14.8		

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
1-23-78	76	15.4	76	14.1		
Task IX Flow Surge 300 psi	80	16.8	77	13.7		
	80	16.0	77	13.3		
	80	16.6	77	14.2		
	80	14.1	83	11.9		
	81	13.4	84	11.4		
	84	14.6	84	12.9		
	80	13.9	80	11.0		
	80	13.5	82	10.8		
	80	13.0	80	10.8		
	82	13.0	88	10.3		
	76	16.1	77	12.4		
	81	15.5	82	11.4		
	81	15.8	82	11.9		
	81	15.5	77	11.7		
	81	15.8	77	11.6		
	80	15.5	80	11.9		

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
1-24-78	81	18.1	78	13.9		
Task IX Flow Surge 300 psi w US	81	16.9	78	13.0		
	81	17.3	78	13.2		
	81	19.0	78	14.4		
	81	16.8	78	12.5		
	81	15.2	78	11.7		
	81	15.9	82	11.9		
	82	15.0	82	10.8		
	82	15.6	82	11.7		
	82	14.7	82	11.1		
	82	15.6	79	11.7		
	82	14.4	79	11.1		
	82	15.6	79	10.8		
	82	14.7	79	10.6		
	82	15.3	82	10.8		
	82	13.6	82	9.0		
	82	13.8	81	9.7		
	81	12.9	81	8.5		
	81	13.6	81	8.9		
	81	12.6	81	8.5		
	81	13.8	81	9.6		
	82	12.7	82	7.8		
	82	13.3	82	8.4		

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
1-25-78	72	17.1	73	10.0		
Task IX Flow Surge 300 psi w US	72	16.0	70	11.2		
	76	16.0	82	11.2		
	76	15.9	80	10.6		
	76	15.5	80	10.9		
	72	15.1	80	9.2		
	74	14.7	76	8.6		
	74	14.2	74	8.2		
	74	14.2	74	7.9		
	74	14.2	78	7.9		
	75	14.2	78	7.9		
	75	13.9	75	7.6		
	79	14.2	75	7.9		
	79	13.9	75	7.6		
	79	14.2	75	7.9		
	79	14.2	75	7.6		
	78	14.2	75	7.9		
	78	13.9	78	7.6		
	78	14.2	78	8.2		
	78	13.9	78	7.9		
	78	14.2	78	8.2		
	78	13.9	78	7.6		
	78	14.2	78	7.9		

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
1-26-78	79	18.5	75	13.4		
Task VII revised Flow Surge 50 psi w US	75	20.8	75	17.3		
	78	18.9	78	16.2		
	78	19.0	78	16.4		
	78	20.0	78	17.0		
	80	18.5	77	16.3		
	77	17.9	77	15.8		
	77	17.5	77	15.5		
	77	18.8	77	16.0		
	80	17.4	80	15.2		
	79	16.8	79	14.7		
	79	16.8	79	14.7		
	79	17.8	79	15.7		
	80	17.3	80	15.0		
	80	16.7	80	14.5		
	79	16.7	79	14.5		
	79	17.7	79	15.0		
	80	17.3	80	14.5		

DATE	RO-1		RO-2		UF	
	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
1-27-78	74	18.0	74	14.9		
Task VII revised Flow Surge 50 psi w US	79	17.4	79	14.1		
	81	17.5	81	14.6		
	81	18.8	81	14.6		
	79	17.2	79	14.3		
	79	16.9	79	14.3		
	80	16.9	80	14.0		
	80	17.5	80	14.6		
	79	16.7	79	14.6		
	79	16.7	79	14.3		
	79	16.7	80	13.5		
	79	17.3	80	14.3		
	80	17.1	79	14.0		
	79	16.7	79	14.3		
	79	16.4	79	14.0		
	79	17.3	79	14.3		
	80	16.7	79	14.3		

TE	RO-1 % REJ	RO-1 FLUX	RO-2 % REJ	RO-2 FLUX	UF % REJ	UF FLUX
1-30-78	40	18.3	72	11.8		
Task VII revised Flow Surge 50 psi w US	78	17.0	78	14.4		
	78	17.0	78	13.0		
	78	15.5	78	13.5		
	78	16.4	81	13.1		
	78	16.0	78	11.2		
	78	16.8	78	11.7		
	78	15.3	78	10.1		
	78	13.1	78	11.1		
	78	14.6	80	9.0		
	78	15.5	78	9.3		
1-31-78	63	16.7	37	11.7		
Task VII revised US 0 psi	78	14.4	78	9.9		
	78	13.8	80	8.3		
	70	15.4	81	12.3		
	80	15.7	82	11.4		
	80	13.9	82	10.1		
	82	14.0	83	10.4		
	81	14.3	81	9.9		
	82	15.1	83	10.7		
	83	14.4	84	10.0		
	83	13.9	83	9.7		
	83	14.3	83	10.2		

	RO-1		RO-2		UF	
TE	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
2-1-78	82	16.1	83	10.1		
Task VII revised US 0 psi	76	16.2	76	9.6		
	85	15.7	83	10.8		
	74	15.1	74	10.4		
	76	16.0	85	11.1		
	77	15.6	87	11.3		
	76	15.0	87	10.7		
	73	16.4	73	11.2		
	76	16.3	87	11.4		
	76	14.6	74	10.3		
	74	13.5	74	10.2		
	74	15.0	74	11.0		

	RO-1		RO-2		UF	
..TE	% REJ	FLUX	% REJ	FLUX	% REJ	FLUX
2-2-78	60	16.7	52	12.5		
Task VII revised US 0 psi	74	16.0	79	10.7		
	74	16.3	74	10.8		
	74	15.9	76	10.4		
	76	15.5	87	11.0		
	80	13.4	89	8.8		
	78	13.6	89	9.0		
	79	13.3	88	8.7		
	89	11.1	87	7.1		
	89	11.1	89	7.1		
	81	11.9	85	9.0		
	89	11.6	85	7.4		
	78	11.3	80	7.3		
	78	12.1	80	8.9		
2-3-78	63	12.1	63	9.3		
Task VII revised US 0 psi	78	11.0	78	8.5		
	78	11.2	78	7.8		
	76	10.5	76	7.9		
	78	10.1	78	8.6		
	80	9.1	80	7.6		
	78	9.8	78	7.6		
	78	9.9	78	7.6		
	80	8.7	81	7.3		
	80	8.8	78	7.6		
	80	9.7	78	8.1		
	80	9.5	78	8.1		